

## PACMod 3.0 System Polaris Ranger

The PACMod 3.0 System at the heart of the AutonomouStuff Polaris Ranger automated research development vehicle provides comprehensive drive by-wire capability. Customizable system configurations accommodate a wide range of research subjects and autonomous applications. The current firmware version generates vehicle feedback data, and regular firmware updates will further enhance research potential. The following tables illustrate vehicle performance with PACMod installed.

### Acceleration

Commanded % pedal position is orange and vehicle speed in meters per second is green, versus time in seconds. Table 1 shows manual mode, and Table 2 in by-wire mode.

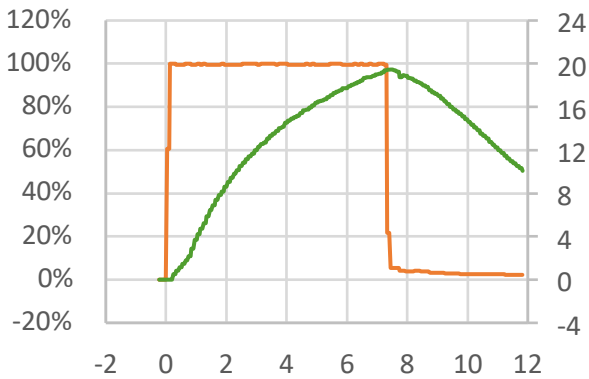


Table 1

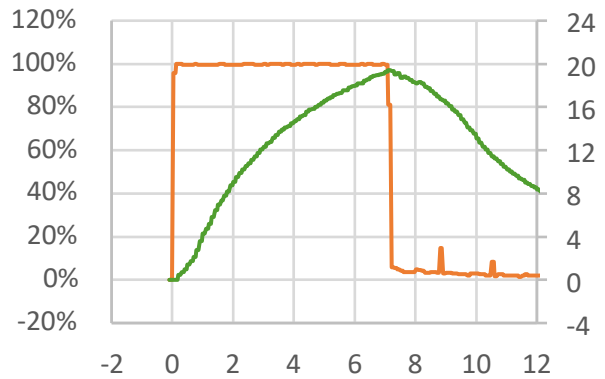


Table 2

### Braking

Commanded % pedal position is orange and vehicle speed in meters per second is green, versus time in seconds. Table 3 shows manual mode, and Table 4 in by-wire mode.

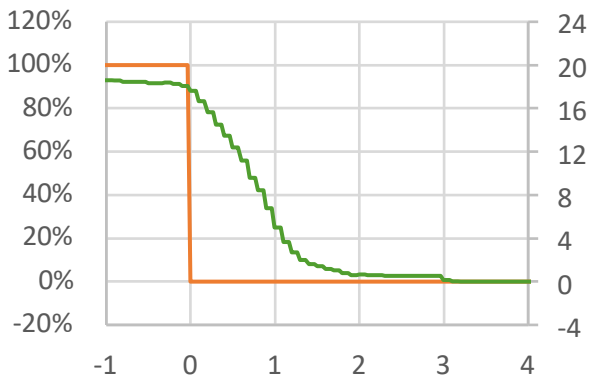


Table 3

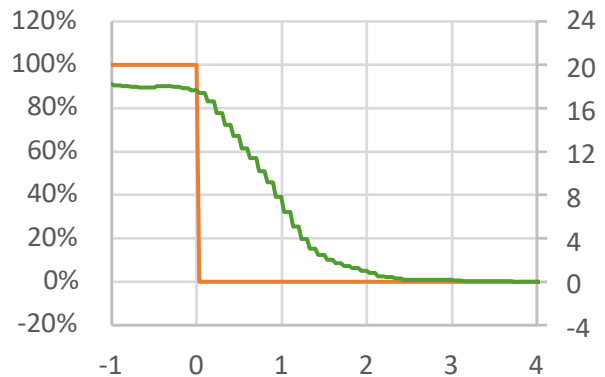


Table 4

### Steering: Full-range step

Commanded steering wheel position is orange and measured in radians; actual steering wheel position in radians is green, versus time in seconds. Rate limiting set to 6rad/s. Table 5 is at 0mph, and Table 6 is at 5mph.

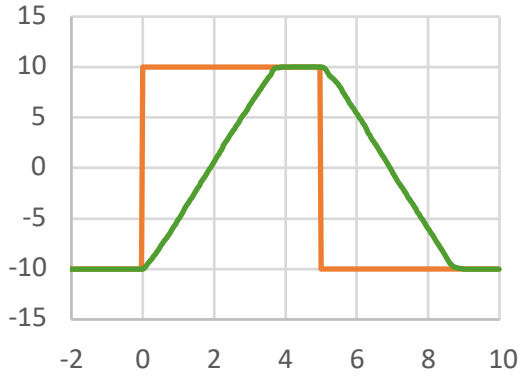


Table 5

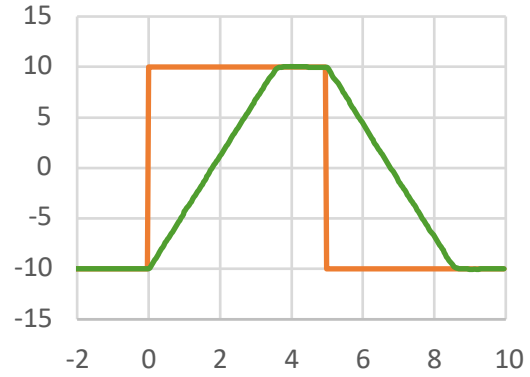


Table 6

### Steering: 90-degree step

Commanded steering wheel position is orange and measured in radians, actual steering wheel position in radians is green, versus time in seconds. Table 7 is at 0mph, and Table 8 is at 5mph. Rate limiting set to 6 rad/s. Table 9 is at 0mph, and Table 10 is at 5mph. Rate limiting set to 3.3 rad/s. Firmware version 1.1.4.

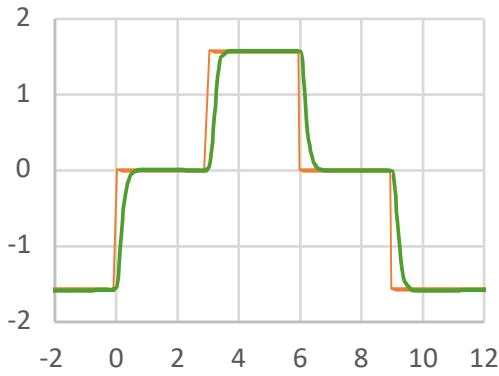


Table 7

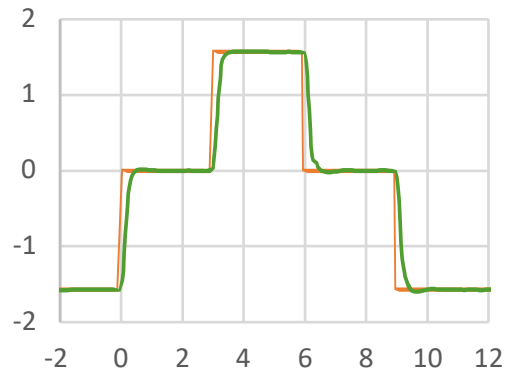


Table 8

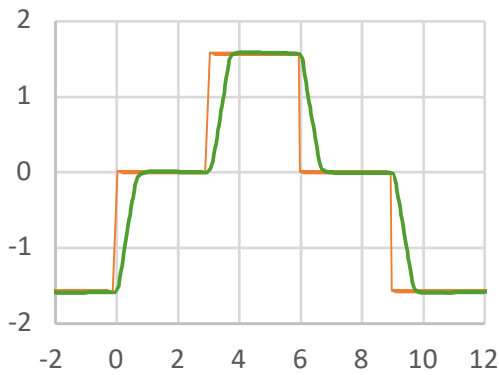


Table 9

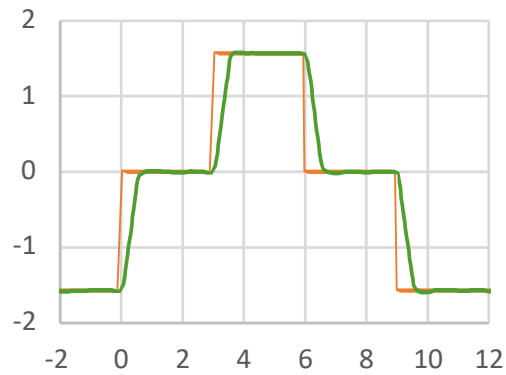


Table 10

Systems	Signal description	Limit <sup>1</sup>	Overshoot <sup>2</sup>	Resolution <sup>3</sup>	Latency <sup>4</sup>
Steering	Steering wheel angle command (rads)	10.3 radians	< 1% <sup>5</sup>	0.003 rad	< 50 ms <sup>8</sup>
	Steering wheel angle feedback (rads)				
	Steering wheel angle rate (limit) command (rad/s)	12 rad/s <sup>6</sup>	-	0.003 rad/s <sup>7</sup>	
Throttle	Throttle command (percentage)	0% to 100%	0 <sup>10</sup> %	0.15% <sup>11</sup>	< 50 ms <sup>8</sup>
	Throttle plate position (percentage)	0% to 100% <sup>9</sup>			
Brake	Brake command (percentage)	0% to 100%	0%	0.25% <sup>12</sup>	< 50 ms <sup>8</sup>
	Brake command feedback (percentage)				
Shift	Shift command (R/N/DH/DL/P) – Takes about 1.5s to shift.	-	-	-	< 50 ms <sup>8</sup>

The diagram below generally represents a vehicle system under by-wire control. The notes below reference this diagram.

<sup>1</sup> This is the commanded value limit based on the physical limits of the operator control and other control considerations. Unless specified, the feedback limit may be the same as or somewhat larger than the command limit.

<sup>2</sup> The overshoot is a characteristic of the dynamic physical response of the operator control. This is not the dynamic response of the vehicle.

<sup>3</sup> This is the granularity of the command and the feedback.

<sup>4</sup> Latency for the command is the time required for the command signal to travel from the User PC to the ECU. Latency for the feedback is the time required for the feedback signal to travel from the ECU to the User PC.

<sup>5</sup> Overshoot in the response of the steering wheel increases with the size of the step command and the steering wheel angle rate limit command. This overshoot was measured with the command set from 0 to 10 radians and the steering wheel angle rate limit command set to 6 rad/s.

<sup>6</sup> Steering rate limit commands set above 9 rad/s have little effect.

<sup>7</sup> The command message resolution is 0.001 rad or 0.001 rad/s, but the ECU limits the actual resolution.

<sup>8</sup> A response to a change in the command signal at the User PC can typically be measured in the feedback signal at the User PC within the time necessary to receive two User CAN feedback messages. The limiting factor is the asynchronous transmission rate of the command and feedback messages at a frequency of 30Hz, or a period of 33.3ms. Therefore, the latency then is up to 33.3ms to receive the first feedback message after the command message plus 33.3 ms for the next message, which adds up to < 66.6 ms. Dividing 66.6 ms by 2 gives an estimate for the latency of the command and feedback signals individually to the ECM and User PC respectively.

<sup>9</sup> Throttle commands between 0% and 40% produce throttle plate movement between 0% and 100%.

<sup>10</sup> The PACMod is not moving an operator control, but instead overriding the operator control output signal.

<sup>11</sup> Based on analog to digital conversion resolution.

<sup>12</sup> Based on 1.2 rad of travel and 0.003 rad ECU resolution.

